CHAPTER 18
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Design and Construction of an Electro-Mechanical Bowling System

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INTRODUCTION

This project describes the design and construction of an electro-mechanical device to help handicapped people candlepin bowl more independently. Five sub-systems were designed: an aiming system, a firing system, a reloading system, a user interface, and electronic logic to control all of the systems. The user controls all aspects of the aiming and firing of the bowling ball. With a control panel, the user can move a joystick to change the aim, slide a lever to change the speed, or push a button to fire a ball. The aiming system allows the user to control where the ball is fired both laterally and rotationally. The firing system is powered by a compressed spring. Once the ball has been fired, the reloading system automatically loads another ball. Each mechanical sub-system was constructed and tested to assure the system worked as intended. The system will be used as an educational and recreational device.

STATEMENT OF IMPACT

People with physically disabling diseases are becoming a greater part of society. Physically challenged people must be able to become more independent. One of the ways this is accomplished is by designing equipment that allows handicapped individuals to enjoy recreation frequented by non impaired citizens. Many times the recreational part of the physically challenged individuals' lives is ignored by technology. Candlepin bowling is one activity that many handicapped people enjoy. Currently, at our client institution, a handicapped youth has an assistant move a metal ramp into position, and place a ball on the ramp. The bowler then pushes the ball to begin its rolling down the ramp and onto the alley. In some cases, the handicapped bowler does have the ability to position the ramp himself/herself. Because of the design of the ramp systems, this process becomes awkward. Often the individual does not have the muscle control required to move the ramp small distances required to accurately aim the ramps. The design and construction of an automated bowling machine allows handicapped individuals to participate more independently in candlepin bowling. The device does not simplify the game to the point where strikes are thrown every time. This allows the user to make physical changes to the system to change the launching position as well as direction and speed of the ball. We feel that the students at the Massachusetts Hospital School will get many hours of recreation with this machine.

TECHNICAL DESCRIPTION

The goal of this project is to design and construct a system that allows the youth at the Massachusetts Hospital School (MHS) to bowl more independently, without eliminating the challenge that is inherent in the game.

The final design consists of five main sub-sections, the base and cover assemblies, the launching system, the positioning system, the ball supply system, and the control panel/user interface. Figure 18.1 shows an overall view of the entire machine without the Plexiglas cover.

The base and cover assemblies serve two main functions, to enclose the system so that people will not get hurt from it and to connect the other sub-systems, aside from the control panel, together. The base allows the system to be leveled, and to keep the system from moving on the floor. The physical configuration of the base is one that allows the staff at MHS to very quickly and easily take the system apart, and to reassemble it. The base is divided into two major sections. The right side of the base, when facing the alley, is the area that houses the linear slides and the firing systems. The left side houses all of the electronics and the logic that controls the operation of the device. The cover for this system is created out of four pieces of Plexiglas. This is a freestanding part of the system. The ***cover*** encloses all of the other systems, and helps to prevent people from being injured by getting a finger or any other body part caught in the system while it is in use.

The launching system is the portion of the system that controls all aspects of firing the ball. This includes adjusting for the different ball velocities, releasing the latch to fire a ball, and resetting after a ball has been fired. The firing system works like the spring launcher for a pinball machine. The front of the spring is compressed against a latch system. When the latch is released, the front of the spring is free to move forward, which in turn moves the ball that rests against the front plate of the spring. After a ball is fired the front of the spring is pulled back behind the latching device. The back of the spring is then moved forward to compress the spring. Once the spring has been compressed to the amount designated by the speed control on the control panel, the system is ready to be fired.

The launching system is constructed from three main component groups: the spring assembly, a compression/reset device, and a latch system. The spring assembly consists of three parts, the spring, and two plates that mount to the spring. The rear plate, which mounts to a compression block driven by a linear actuator, is constructed of steel and prevents the spring from flying free when a ball is fired. The front plate is the portion of the spring assembly that interacts with the latch system.

The compression/reset system consists of three main components, a linear actuator, a compression block, to which is attached to the spring, and a latch system. The spring is reset and compressed via a linear actuator and compression block combination. The linear actuator and the compression block are linked via a super nut that is press fit into the compression block. This nut converts the rotational motion of the actuator to the translational motion of the compression block. To prevent the linear actuator from over compressing or resetting too far, two limit switches were installed.

The compression block rides on two TGP steel rods. The bearing surfaces between these rods and the aluminum compression block are four oil impregnated brass bushings. The latch system is constructed from a four bar linkage. Using a four bar linkage allowed a latch to be constructed that would require very little force to open. This is because the linkage can be placed in toggle, and thus used as a truss system rather than a linkage. This linkage was specifically designed to withstand the 300 lb. that the spring exerts during full compression. The linkage works very much like a vise grip. The front spring plate is wedged against the latch, and the latch support.

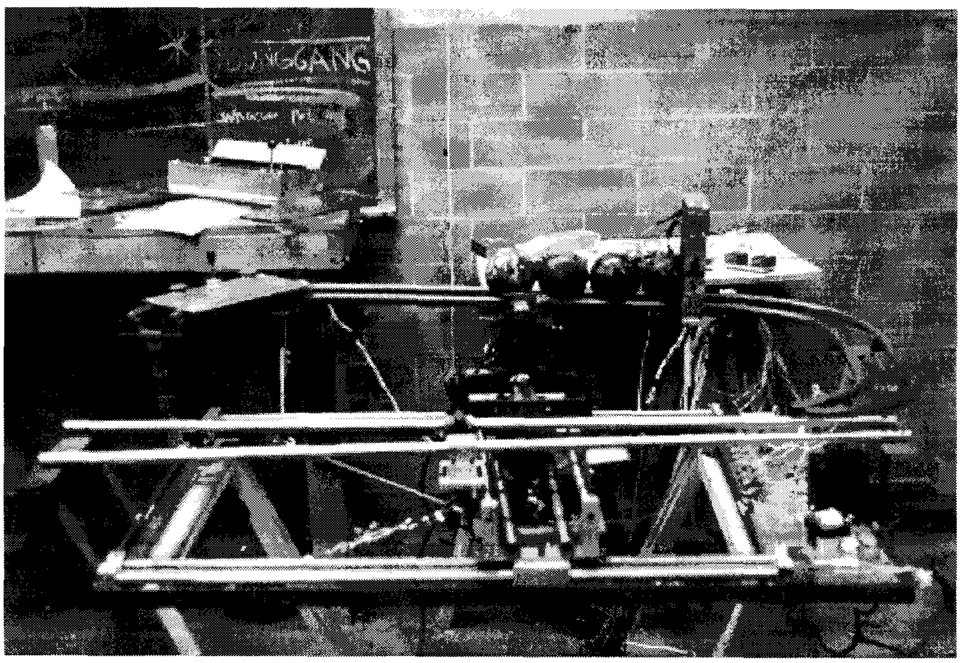

Figure 18.1. Electra-mechanical Bowling Machine [without cover].

The latch support consists of two steel members that sit between the launch rails. The latch and the latch support wedge the front plate of the spring from the top and bottom of the spring plate. This holds the front of the spring fixed until the ball is fired. A solenoid was chosen to actuate the latch. This solenoid, which has a maximum lift of 23 lb. at 1 inch, has two purposes; to lift the latch to cause the spring to release, and to lift the latch to allow the front spring plate of the spring to go by while the system resets. The solenoid is attached to the latch release. The last portion of the launch system are the guide rails for the ball. These rails are wider apart toward the rear of the machine than where the ball leaves. This ensures that the ball will rest against the front plate of the spring rather than sitting in front of the plate when the device is level. For safety, a limit switch was placed between the two guide rails. This switch is depressed when the ball is ready to be fired. The logic circuit/control system allows the solenoid to release the latch when a ball is in front, and touching the front spring plate.

The positioning system controls the placement of the launching system so that the balls can be fired in the desired direction and position on the alley. This system physically moves the launching system relative to the base in either a translational or rotational manner.

The positioning system consists of two linear slide assemblies, both of which are mounted to the base. One assembly is positioned at the front of the device, and attaches to the front plate of the launching system. The second assembly is positioned at the rear of the device and attaches to the linear actuator support block of the launching system. The positioning system aims the launching system. This provides both the translational and rotational motion for the launching system. To move in a purely translational manner both the front and the rear slides move in the same direction and with the same velocity. To rotate the launch assembly clockwise, the rear-sliding block moves to the left. To rotate counter-clockwise the rear slide block moves to the right. During all rotations, the front slide block remains stationary.

To maintain a constant flow of balls there is a supply system. The balls are removed from the existing return system in an alley, and then stored in the storage area of the supply system. Through the use of a gate, this system regulates the flow of balls to the launching system. The ball supply system has two primary operations, removing the balls from the bowling alley's return system and controlling the flow of balls to the launching system. This is accomplished with a rail system that takes the balls from the return system and stores them. The flow is controlled by a gate system that is attached to the rails. To control the flow of balls to the launcher, a gate was constructed. This gate uses a solenoid to raise a panel that allows a ball to pass when it is in the lowered position. To assure that the solenoid is be able to pull the aluminum plate up, a low coefficient of friction is required between the plate and the tracks in which it moves.

All of the mechanical movement in the bowling machine is controlled with a console that can be connected directly to the bowler's wheelchair. The console consists of two launching buttons, for right- and left-handed players, a slide-bar for controlling the speed at which the ball will be launched, a joystick for aligning the launching mechanism, and a LED display which indicated READY, NO BALL IN STORAGE RACK, POWER and the speed of the ball as a fraction of the maximum speed. All the functions of the panel are independent. The control panel has three primary components; a joystick, a speed control slide and a push button. The joystick controls left and right translation as well as clockwise and counterclockwise rotation of the ball launcher. The speed control slide is simply another arm protruding from the upper surface of the panel that allows the user to control the point to which the spring is compressed, and therefore the speed of the ball. A row of LEDs displays the setting of the slide. The last interfacing components of the control panel are the two push button momentary switches. These are used to send the signal to fire a ball. These switches are industrial strength switches, with a very light action. This will enable the switches to withstand the forces of users hitting them with a lot of force, something every teenager is apt to do. The two firing buttons allow either a right- or a left-handed person to push one of the buttons without hitting the joystick. This helps prevent the user from accidentally changing the aim of the system when he/she goes to fire a ball. To help users remember what each function of the control panel motions are, small labels indicating the motion are placed around the controlling parts. The control panel is designed to attach to a universal lap tray.

The control console connects with the mechanical components of the system via a digital logic circuit. Several switches throughout the system indicate when mechanical parts have reached the limits in their range of movement. Other switches indicate the presence or absence of a ball at various points in the system. The indications from switches are fed back into the main circuit, and are used to interrupt signals controlling motors and solenoids, and for allowing or disallowing certain movements during specific stages of the bowling process. A major example of the use of these switches can be found in the sequential portion of the circuit. This section of the circuit controls everything that happens after the launch button is pressed. This sequence is shown below.

- Launch button pressed
- Check for no movement in the system
- Allow release of latch, launching ball
- Pull block and spring all of the way back
- Close the latch
- Release the next ball in rack, if present
- Compress the spring
- If ball is in position, wait for next launch call

Within the steps, the circuit is asking specific questions: Is the latch open or closed? Is the block all of the way back? Has a ball passed through the gate on the rack? These, and other relevant questions, must be answered before the circuit continues to the next step of the sequence. An indication of which step is currently being carried out are in the form of a binary code, generated by a 74LS163 "Binary Counter." Logic gates detect when the proper signals are present for a given step in the sequence. When they are there, the sequence is allowed to continue, by toggling the "enable" input of the counter. The primary reason for automating this procedure is to limit the errors and complexity in the commands given the machine by the user. In other words, there will always be a ball before a launch is allowed, the latch will open when the spring is being brought back into place, the user does not need to reset the spring, etc. The sequential circuit works in conjunction with the main logic circuit. The main circuit is made up of logic gates. Eight separate subsections are given requests for different movements or actions. Limiting signals, respective to each subsection, are used to determine if the action can be allowed, and, also, to stop a signal that is already being passed to the mechanical system. The importance of this is obvious. If a request for movement is wired directly to the motor, solenoid, etc. that is to be turned on, then damage would occur if the mechanism has reached one of its limits. Motors could burnout, drive-nuts could be stripped, worm gears could be warped, etc.

Transistors and relays are used to direct the power to the proper device. The transistors, used as switches, are controlled by the outputs of the eight subsections of the main circuit. When the transistor is turned "on", the relay, which is in series with the transistor, closes and the motor or solenoid is given the power, with the right polarity, to turn on.

The system can be completely assembled by one person in less than 20 minutes. It should be noted that this might take longer for a person that is unfamiliar with the system. Due to the size and the complexity of assembly it is recommended that when the system is taken apart that the sub-assemblies, the sliders, the launching system, and the rails are not disassembled. If these components are disassembled, it will require more time to assemble the entire system. The system can to be carried by two people. Based on the weights of the individual sub-systems the overall weight is approximately 175 lb. The heaviest individual component is the launching system, which weighs about 65 lb. It can be carried by one person. Fully assembled the device occupies a space of 5ft. x 4ft. x 2ft. Total cost of the bowling machine was approximately $500.

Design, Construction and Evaluation Of a Portable Bow Mount System

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INTRODUCTION

A handicapped youth required a device that would support a standard bow for the sport of archery. A portable bow mount device was designed and manufactured to attach to the left side of a wheelchair. The device is designed to allow different users to adjust the position of the bow and aim towards the target. The bow is supported on a curved beam whose center of curvature is located at the shooter's right shoulder. An aiming device, with two independent degrees of freedom, allows the user to adjust the azimuth and elevation of the trajectory of the arrow and lock the bow in place for shooting. The modular design of the device facilitates attachment to different wheelchairs using custom mounting brackets. Test results indicate that accurate and repeatable trajectories can be obtained by experienced shooters using this device. Archers with disabilities can use the device for practice and competitions.

STATEMENT OF IMPACT

The objective of this project is to design and build a device to allow physically disabled people to compete in archery. The device will be used for rehabilitation, enhancing capabilities and improving the confidence of those who use it. Archery is a challenging sport with many competitions for the handicapped, thus, there is a large demand for adaptive equipment. The value of the device as a rehabilitation tool will be greatly increased if it can be used by many people. The client is hemiplegic with the disability affecting primarily the left side of his body. He uses his right arm to pull the bow. The device compensates for his left side by holding the bow in a stable position while offering the degrees of freedom necessary for aiming. The device must also use as much of the client's abilities as possible to challenge the user and be an effective tool for rehabilitation. The portable bow mount system is designed and manufactured as a universal rehabilitative tool for the left side of the body. The device allowed the client to participate in archery without the use of his left arm and hand. This client expressed much appreciation for the system's abilities, aesthetics and easy methods for operation. The system allowed one to improve or learn basic archery skills. This system can be used in archery by persons of all skill levels.

TECHNICAL DESCRIPTION

The five primary functional requirements that the device must satisfy are aiming, adjustibility for different clients, bow and shooting conditions, resistance to forces, and a lockable aiming device. In order for the system to function, it needs 5 degrees of freedom (DOF). Two degrees of freedom are needed for the functional requirements of aiming. Aiming is achieved by changing the angles that the arrow makes with respect to the target. Additionally, three DOF's are needed to accommodate adjustibility of the device to the client or adaptability to different clients. The three degrees of freedom must position the bow laterally, vertically and forward or backward with respect to the shooter. The device must also be able to resist the forces applied to it through the pulling of the bowstring and the shooting of the arrow. A means to hold the position of the bow in place while shooting is another functional requirement that must be met.

The portable bow mount system consists of three modular sub-systems (mounting system, aiming device and bow holder) , which were then assembled into one comprehensive system as shown in Figure 18.2. This system provides height adjustment, rotational adjustments for aiming, rotational adjustment of the bow and aiming device with respect to the user, translational height adjustment, portability, adaptability and minimum weight constraints.

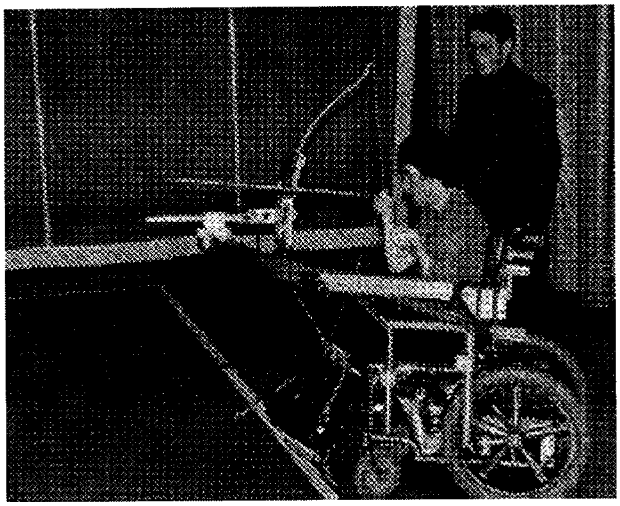

Figure 18.2. Handicapped archer with portable bow mount system

The wheelchair mounting system consists of a space frame and curved member. The design is composed of a curved square tube (the curved member) connected to a straight square tube, four tubes in a plane 62 degrees from the horizontal, a hollow mounting leg, a smaller solid mounting leg and locking collars for both mounting legs (which provide for height adjustment within the mounting brackets). A mounting bracket is designed for the client's chair. The larger rear mounting leg is designed to insert into the mounting bracket, while the front leg mount is designed to insert directly into the footrest holder of the client's wheelchair. The system is adaptable to different wheelchairs by manufacturing custom brackets for each wheelchair to securely hold the two legs of the space frame. The wheelchair mounting system allows for vertical height adjustment for different users and wheelchairs by the repositioning of the collars along the length of the legs. The exact diameter of the legs and the material selection are decided upon by an in-depth evaluation of the stresses on the components. The diameter of the curved member is selected for maximum adjustibility of the aiming device with respect to the user. The curved member has a square cross-section to accommodate the mounting bracket of the aiming device. A solid bracket of aluminum is located in one end of the curved member. This block, which is pressure fitted to the curved member, inserts directly to the straight square section. The members are held together by a pin. The ability to separate these pieces increases portability of the mounting system. The lengths and angles of the four hollow tubes of the mounting system are influenced by the distance of the bow from the user. The diagonal member provides rigidity and stress relief to the surrounding structural members. The aiming device is mounted to the curved member by the mounting bracket (square clamp). This mounting bracket adjusts along the curved member to allow placement of the bow in various positions relative to the user. The shooter's right shoulder is the approximate center of curvature for this range of motion. The design of the portable bow mount system uses this range which pivots about the right shoulder. This degree of freedom is translational along the curved member and ranges from directly in front of the user to 68" to his/her left. The optimum position of the bow should be determined by the user. Two concentric tubes on the aiming device fit into the mounting bracket. The inner tube slides within the outer tube to allow the user the reach distance through a range of 9 inches. The inner tube is also be turned within the outer tube. This allows the user to tilt the bow to one side. Once the reach and tilt of the bow are set, the outer tube is tightened onto the inner tube to lock the position. One plate is welded directly to the inner tube, while the others are attached with bicycle cams. The aiming device allows for two rotational degrees of freedom. The degrees of freedom are tightened before drawing and shooting of the bow and loosed during aiming. These two degrees of freedom are not coupled, resulting in one axis affecting only the horizontal angle of arrow flight (azimuth), while the other affects its angle of elevation. Cams, commonly used to offer a range of motion when unlocked, offer a secure aim when locked. Note that the positioning of the wheelchair relative to the target may also be utilized for coarse adjustment to aim. The aiming device may then be used for the fine adjustment to aim. The final component of the design is the bow holder. The aiming device is welded directly to the flat plate. The bow holder secures the bow to the flat plate by using two padded hose clamps that insert directly through the four rectangular holes of the flat plate. The system weighs less than twenty pounds. The system is proven highly accurate and repeatable. This was demonstrated by an archer who repeatedly shot 2 arrows, which hit within one inch of each other, into a target that was 60 feet away. The cost of the project was $288 for materials and $140 for special tooling.

A Secondary Joystick Adapter for Force Reduction

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INTRODUCTION

Commercial wheelchair joysticks are constructed to withstand a limited amount of force. Current designs are at a high risk of failure for users with excessive muscle tone and spasticity, such as those with cerebral palsy. A damaged joystick must be sent out for repair that is not only costly but also frustrating for the client who then becomes dependent on others for mobility. The purpose of this project is to design a customized secondary joystick linkage retrofitted to interface with an Invacare proportional joystick currently used by a client with cerebral palsy. The final design is manufactured mainly by machining aluminum sheets and is encompassed by a plastic housing.

STATEMENT OF IMPACT

For a majority of the day, while the client is not driving his wheelchair, the power switch is turned off. However, because of his affliction and constant accessibility to the control, the client continues to move the joystick and apply unnecessary forces that aggravate the problem of excess force bending the joystick shaft and pins of the pivoting mechanism. When the shaft and pins become bent, the joystick loses the ability to re-center itself and becomes inoperative. The client's excessive muscle tone also causes him to exert a tremendous amount of force on his joystick while driving. The client uncontrollably pushes the Invacare joystick to its maximum excursion, pressing the shaft against its physical stops. The client's joystick usually needs to be sent for repairs three to four times a year due to this failure. The joystick adapter will reduce the forces applied to the Invacare joystick and thus eliminate the frequent repairs needed.

TECHNICAL DESCRIPTION

The final design consists of a rugged secondary joystick connected to the Invacare by two fourbar linkages. The linkage assembly is shown in Figure 18.3 without its housing and the Invacare joystick. A four-walled box with no cover is tightly fitted to the top of the Invacare actuator. Two curved metal brackets are pinned to the outer walls of this box and cross above the Invacare joystick's pivot point at the neutral position, The shaft of the Invacare protrudes through the intersection of these brackets. The secondary joystick is similar in design to the primary joystick, including its centering mechanism. The secondary joystick shaft is thicker than the Invacare shaft to allow for higher loads, if encountered. Note that the curved positioning brackets are inverted below the ball and socket joint of the secondary joystick.

The two joysticks are connected via two fourbar linkages as shown in Figure 18.3. A spring-loaded mechanism on the driver link is designed to relieve the amount of force applied to the Invacare shaft and extend the allowable range of motion of the secondary joystick. This device consists of two v-shaped links and a spring. The two links pivot about the same point and are held together until the Invacare joystick reached its maximum range of motion. At this point, the driver link remains fixed as the second link continues to move with the secondary shaft, extending the spring. The secondary shaft can travel beyond the limits of the Invacare. For the client, this mechanism allows him to extend his range of motion without pushing the Invacare beyond its stop and without applying excessive force to the system.

Experimental studies indicate that the client could move a joystick 45 degrees forward and 45 degrees backward with little difficulty. Thus, the secondary joystick was designed to move within this range. This excursion is 20 degrees larger for each direction than what is currently allowed by the physical stops on the Invacare joystick. The effective range, or the range in that the secondary joystick controls the speed and direction of the wheelchair, is only within the first 25 degrees of the joystick motion from the vertical. The remaining 20 degrees that the secondary joystick is allowed to move does not affect the proportional speed of the wheelchair; the wheelchair maintains constant maximum speed in the direction indicated.

A plastic housing encloses the two joysticks. The housing protects the linkage from any external interference that may cause damage to the system. The housing also serves to protect the user from any injury caused by moving parts in the mechanism. The housing base plate lies directly on top of the client's control box. A square hole, two inches by two inches, was cut out of the base plate so that the lip of the client's Invacare joystick casing would tightly fit within the hole. Because the lip of the Invacare joystick casing raises 0.25 inch above the control box, the top of the base plate lays perfectly flush with the top of the Invacare casing.

The casing, in which the curved brackets controlling the Invacare joystick pivot, is screwed directly into the top of the base plate. The top of the box, in which the curved brackets guided by the secondary joystick pivot (also the ball joint housing), is located 2.25 inches above the top plate. This box is held in position by four long columns that screw directly into the base plate. With this configuration, the entire linkage can be assembled without being completely encased by the housing. This may also be beneficial in the event that repairs or adjustments need to be made to the mechanism; the sides of the housing can be simply removed.

The top plate lies one inch above the base of the secondary joystick box and is screwed directly into the box. A two-inch diameter hole is cut out of the top plate. The shaft of the secondary joystick extends through this hole. The client's hand is located above the top plate where he will control the joystick handle. The edge of the one-quarter inch deep circular hole provides the stops for the secondary joystick. The sides of the housing are then screwed into the top plate and bottom plate. The front and back plates are also screwed into the top and bottom plates as well as the plates on the two sides. The sides of the housing have circular grooves milled out of them to support the pins from which the linkage pivots.

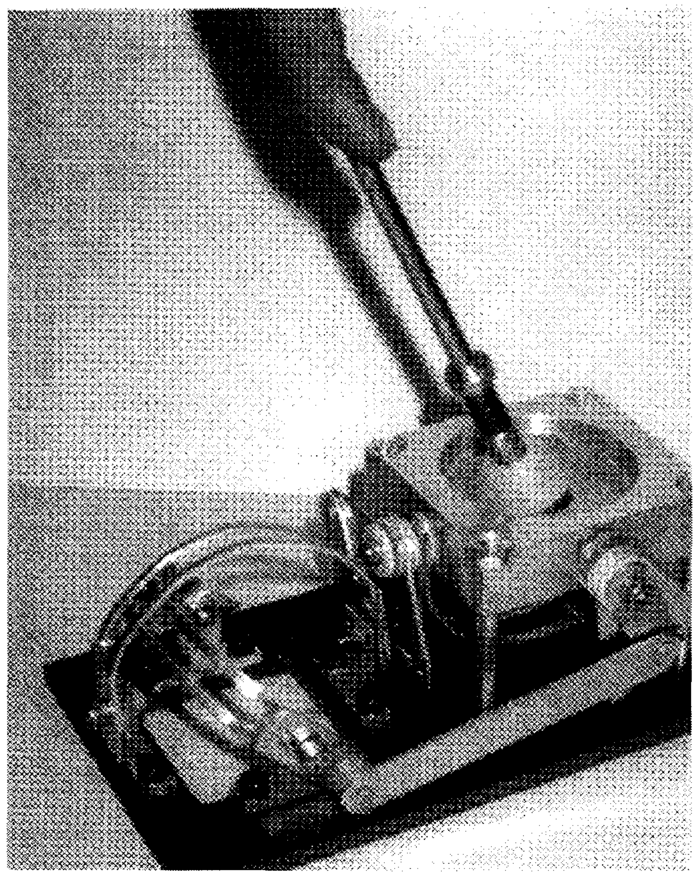

Figure 18.3. Secondary joystick adapter

Total cost of the mechanism was $133.